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RESEARCH ON AIR POLLUTION ASPECTS OF INCINERATION

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Robert A. Taft Water Research Center
Cincinnati, Ohio

1957

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Engineering Research and Development
Community Air Pollution Program
Public Health Service
U.S. Department of Health, Education, and Welfare

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RESEARCH ON AIR POLLUTION ASPECTS OF INCINERATION

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The incinerator research project at the Robert A. Taft Sanitary Engineering Center is under the direction of Mr. Andrew H. Rose, who, as chief engineer of the Los Angeles County Air Pollution Control District, spent several years studying incinerator design criteria relative to their effects on performance characteristics and on the minimization of the discharge of contaminants to the atmosphere. On the basis of this work (1) certain fundamental relationships were developed pertaining to incinerator design factors as they affect discharge of solids, acids, and volatile organic compounds to the atmosphere.

LOS ANGELES STUDIES

A brief review of the Los Angeles findings seems appropriate to provide background for the present study at the Robert A. Taft Sanitary Engineering Center.

In the Los Angeles study the performance of several types and designs of industrial and municipal incinerators was evaluated in terms of atmospheric effluents, grate loadings, combustion rates, air distribution, and ignition chamber geometry. For the most part

these incinerators were tested during routine operation. However, in order to secure additional information on certain units, special tests were performed under different grate loadings and varying combinations of overfire and underfire air ratios.

Combustion Air Distribution

The distribution of combustion air was found to have a significant effect on the total contaminant discharge from the incineration process. Of three different multiple chamber incinerators reported, each showed a substantial reduction in solids emitted to the atmosphere when the predominant source of required combustion air was changed from underfire to overfire. Decreases ranged from 35 to 50 percent. It is of further interest to note that an incinerator with a so called "low" arch operating with predominantly underfire air produced no more solid contaminant than a comparable incinerator having a "high" arch but operating on predominantly overfire air. Subsequent testing of the "low" arch unit demonstrated a further reduction in the effluent grain loading with operation under predominantly overfire air ratio.

Ignition Chamber Proportions

It was found that three basic relationships must be considered in evaluating ignition chamber proportions: (1) grate loading, (2) arch height, and (3) length to width ratio of the fuel bed. Using the minimum discharge of contaminants with

maximum burning rates as the basis of evaluation, it was determined that the grate loading expressed in pounds per square foot per hour increased logarithmically as a function of total combustion rate expressed in pounds per minute. From the curve of this plotted data, a mathematical relationship was developed indicating:

$$G_L = 16.5 + \text{Log } C_R$$

where G_L is the grate loading expressed in pounds per square foot of grate area per hour, and C_R is the combustion rate expressed in pounds of fuel burned per minute.

It must be kept in mind that this evaluation was made in terms of the limitations imposed by atmospheric contaminant discharge and is somewhat at variance with conventional grate loading concepts.

Ratio of Arch Height to Grate Area

Evaluation of incinerator performance in terms of maximum burning rate with minimum discharge of contaminants demonstrated that arch height varied as an exponential function of the grate area. The mathematical expression of the logarithmic plot gives:

$$A_H = \frac{6}{5} (G_A)^{4/11}$$

where A_H is the maximum distance between the grate level and the arch expressed in feet, and G_A is the area of the fuel bed expressed in square feet.

The data collected in the Los Angeles studies were

insufficient to allow a precise correlation of the ignition chamber proportions in terms of length-to-width ratio of the fuel bed. There was some indication however that satisfactory results can be obtained with ratios varying between 1 to 1 and 2 to 1 with the larger ratio desirable in the small incinerators, i.e., those having a loading below 200 pounds per hour. Large capacity incinerators appear to have a satisfactory discharge characteristic when the length-to-width ratio approached 1.0 to 1.0.

Because the Los Angeles studies indicated that inferior performance and discharge characteristics occurred when the design of the ignition chamber (or primary combustion stage) was inadequate, the emphasis in the Los Angeles study was placed on the primary stage of the incineration process.

INCINERATION RESEARCH AT THE SANITARY ENGINEERING CENTER

Experimental Incinerator

A small scale multiple chamber incinerator was built for these tests. This unit has a grate area of 6.5 square feet and was designed to permit changing the physical dimensions of both primary and secondary combustion stages including length-to-width ratio, arch height, and various dimensions of the mixing chamber and of the final combustion chamber. Arrangements have been made to equip this unit with either a flat arch or an elliptical reflecting arch. The unit was built in sections by

pouring high temperature castable refractory 4 inches thick onto sheet steel frames which were then bolted together to give the desired proportions. For the first series of tests the unit was constructed with a length-to-width ratio of 2 to 1 in the primary combustion chamber. The grate area is held constant, 8.5 square feet. The first tests are being conducted with an elliptical arch so placed in relation to the grate as to reflect radiated heat to the front third of the incinerator grate. Fuel charging is through a front opening guillotine type door; the grate slopes 30° from front to back and is a maximum of 31 inches from the arch. As the study progresses the distance between arch and grate is to be varied within the limits of the incinerator. Stoking is by hand. The reflecting arch location will vary from its present high point, reflecting to the front third of the grate, to a symmetrical placement which moves the zone of reflection farther back in the chamber.

Immediately behind and in line with the ignition chamber is the mixing chamber through which the gases pass in a downward direction as they mix with secondary air introduced along the back side of the bridge wall. The gas stream enters the expansion and final combustion chamber near the bottom and discharges diagonally across this chamber near the top through a 13-inch diameter breeching into a 16 1/2-inch diameter stack 25 feet high. The lower 10-foot portion of the stack is lined with 2 inches of castable refractory.

Upon completion of the present series of tests on the unit, the reflecting arch will be relocated or replaced with a flat

arch; the sloping grate will be relocated in relation to whatever arch is used and will eventually be replaced with a flat grate. Further changes in geometry will involve enlarging or decreasing the size of the flame port, the downpass mixing chamber, and the final combustion chamber, each change to be checked with a series of tests.

Upon completion of tests with the geometry of the incinerator arranged for a length-to-width ratio of 2 to 1, the component parts will then be rearranged to give a length-to-width ratio of 1 to 1 while retaining the 8.5-sq. ft. grate area. The various arch and grate relationships and combustion air ratios will then be studied under these conditions. The study of other length-to-width ratios of the combustion chamber will depend to some extent on the results obtained from the 2 to 1 and the 1 to 1 ratios but are not firmly committed at this time.

Another arrangement to be studied will be the change of the unit from an in-line incinerator to a retort type in which the mixing chamber and final combustion chamber are located to the side of the ignition chamber rather than in line and behind it. We have some evidence that this arrangement offers advantages which are reflected in more efficient combustion and lower contaminant discharges than the in-line type, although this deduction is merely an impression at the present time.

Airflow

All openings into the experimental incinerator have been housed with ducts for the measurement of airflow through overfire, underfire, and secondary air ports. Tests are being made under the various conditions of geometry with airflow controlled at any given inlet from no air to as much as 300 percent excess at one or more points.

Fuel

Selection of a standard fuel for this study was based on an analysis of the combustible component of rubbish from various cities. While it would be impossible to select what might be termed a "typical" rubbish, applicable to every community, the combination selected is considered fairly representative of present day municipal rubbish. Two fuels are being used in the study, and differ only on the basis of moisture content. One standard fuel has a 25% moisture content, the other a 50% moisture content. Equal parts by weight of newspapers and cardboard comprise the paper component which is mixed 3 to 1 with wood. Wet leafy vegetables such as lettuce, cabbage and vegetable trimmings are added to bring the moisture content of the entire mixture up to either the 25% or 50% level. Prior to mixing, the materials are reduced to uniform size. The initial concept was to shred the materials into 1/4-inch strips; however, preliminary testing with such shredding has demonstrated a rather high ignition rate of the dry materials. Experimental

runs are being made to ascertain the suitability of using larger sized material in order to reduce ignition rate and provide greater combustion stability between charges.

Charging

In preparing for a test run, the refractory lining of the incinerator must be brought up to temperature by use of a gas burner in the combustion chamber prior to charging.

Charges are then introduced at the front end of the unit in weighed amounts and at intervals determined by the O_2 and CO_2 content of the exhaust stream. The ratio of O_2 to CO_2 at which charges are added is still under study, but efforts will be directed towards maintaining a fairly uniform ratio. Preliminary runs indicate that more uniform results may be possible with small charges added frequently than with larger charges added less frequently.

INSTRUMENTATION

Sampling of the effluent gas stream includes collection and analysis of the solid contaminant loadings, as well as analysis for certain gaseous contaminants. Oxygen content is automatically analyzed and recorded through the use of a Hays Magnotherm Oxygen Analyzer and Recorder, and carbon dioxide content is determined with a continuously operating Hays Condutherem Carbon Dioxide Analyzer and Recorder. Precise

measurement of carbon monoxide is accomplished through continuous analysis and recording, using a Liston-Becker Nondispersive Infrared gas analyzer suitable for measuring concentrations ranging from 0 to 5 percent. Total organic content of the effluent stream is analyzed and recorded by means of an MSA Nondispersive Infrared gas analyzer suitable for measuring concentrations from 0 to 750 parts per million. This instrument is sensitized with a combination of hydrocarbons to give equal sensitivity for carbon to hydrogen stretching bonds when the adjacent carbon to carbon linkage is a single, double, or triple bond. On the basis of information obtained with this analyzer and of results of intermittent grab samples analyzed by either the mass spectrometer, dispersive infrared spectrometer, or the gas chromatograph, additional infrared analyzers may subsequently be obtained for checking one or more specific gaseous components if a material known or believed to be of importance in photochemical reactions exists in the gas stream in appreciable concentrations.

The formation of oxides of nitrogen can be expected under high temperature combustion conditions. The extent of NO_2 in the exhaust stream is determined by use of a continuously operating NO_2 analyzer and recorder. This instrument, similar in principle to the infrared analyzers, utilizes ultraviolet energy and is suitable for detecting concentrations ranging from 0 to 200 parts per million. Measurement of NO_2 by infrared absorption

involved complications resulting from the fact that water absorbs at approximately the same wavelength of infrared as NO_2. While this problem could have been resolved through the use of a double detector type instrument to compensate for the moisture, the cost becomes rather high. The ultraviolet analyzer does not have this interference problem and is expected to produce suitable results.

Temperature measurement throughout the incinerator are obtained by using shielded inconel sheathed "Ceramo" and "Megopak" couples employing 30-gauge chromel and alumel wires. Temperatures are recorded on a 16-point recording potentiometer. Airflow measurements are recorded on Varian rectiliner strip chart recorders employing Hastings thermal-type flow sensing instruments.

Conclusion

From the preceding discussion, it is obvious that a rather ambitious study is outlined involving on the order of 12 dependent and 12 independent variables. The study was originally proposed as a 3- to 5-year study; however, it is believed that with the amount of automatic instrumentation which has been incorporated into the experimental setup, some fairly significant results should be obtained within one or two years.

REFERENCE

(1) Rose, A. H., Jr., and Hoyt R. Crabaugh, Research Findings in Standards of Incinerator Design; in Mallette, F. S., ed., Problems and Control of Air Pollution, Reinhold, New York, 1955, pp. 95-106.